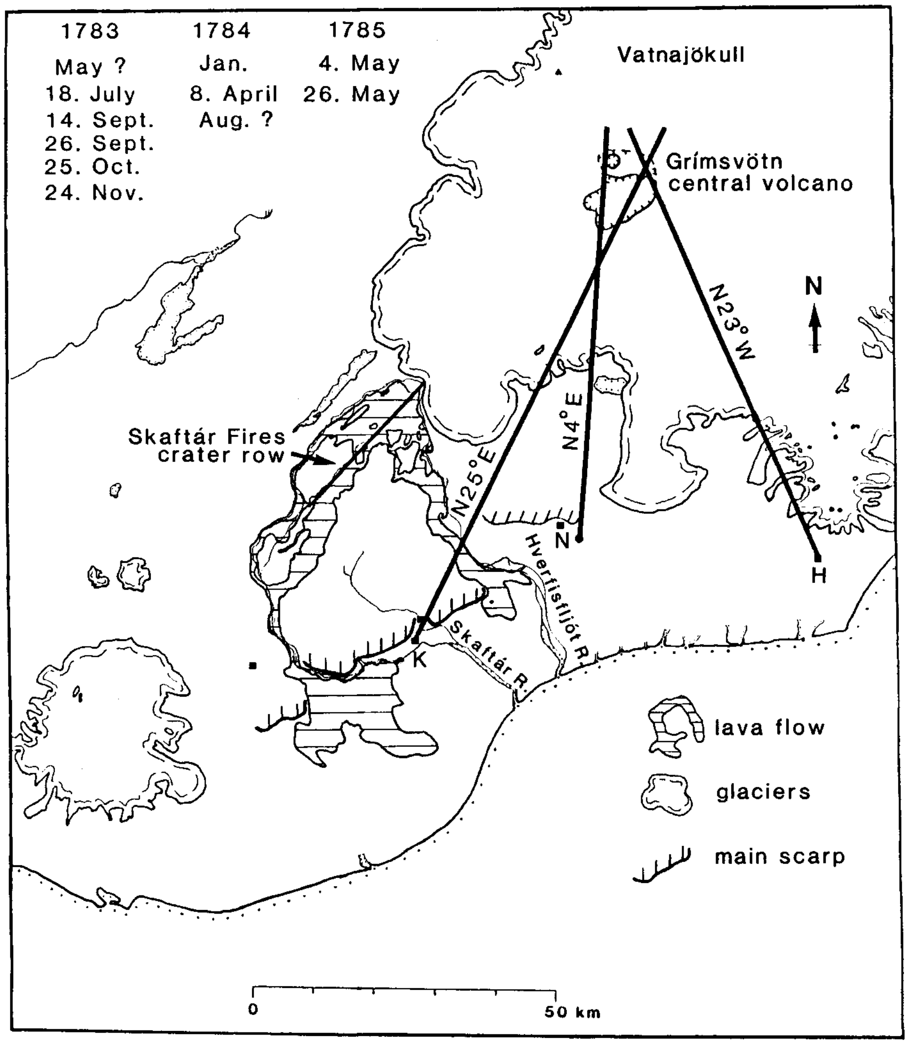

Fig. 1. Map of south central Iceland, showing the Skaftár Fires (Laki) lava flow, which formed 1783–1784. Also shown are the locations from which "fires" were reported, and their directions to Grímsvötn.

rary observers pointed to an area where no historic eruptions had occurred. However, these directions, especially those given in reports from the Sída district, were misleading.

As seen on the old maps, the main scarp in the Sída district (actually an old sea cliff line) was thought to run east-west, but in reality it runs N65°–70°E (see Figure 1). This common but local misconception led to a general clockwise offset of directions (between 20° and 60°) compared to the true geographic directions. A good example is the much-quoted writings of the Reverend Jón Steingrímsson, who resided in the Sída district. Therefore researchers trying to locate the northeasternmost fires on the basis of contemporary descriptions from the Sída district would be off by about 40° southward.

When the observations are corrected for this offset and compared with directional information gleaned from descriptions of the easternmost activity from other nearby areas, it is clear that the "fires" were at the Grímsvötn central volcano. Figure 1 shows the main places where the easternmost "fires" were reported. K is Kirkjubaejarklaustur in the Sída district, where the Reverend Jón Steingrímsson served; N is Núpsstadur; and H is Hof.

Grímsvötn is a large, basaltic subglacial volcanic center with a 35-km^2 caldera. Recent work [*Thórdarsson et al.*, 1987] has shown that Grímsvötn was active throughout 1783–1785, supporting earlier suggestions by *Steinthórsson* [1977] and *Sigurdsson and Sparks* [1978] that the Skaftár Fires fissure basalt eruption was part of a major rifting event on the Grímsvötn volcanic system. The Skaftár Fires (or Laki) eruption is discussed in the article "The Relationship between Volcanic Eruptions and Climate Change: Still a Conundrum" by S. Self and M. R. Rampino on page 74 of this issue.

References

Sigurdsson, H., and R. S. J. Sparks, Lateral magma flow within rifted Icelandic crust, *Nature, 274,* 126, 1978.

Steinthórsson, S., Tephra layers in a drill core from the Vatnajökull ice cap, *Jokull, 27,* 2, 1977.

Thórarinsson, S., *Vötnin Stríd: Saga Skeidárhlaupa og Grímsvatnagosa,* Bókaúgafa Menningarsjóds, Reykjavík, 1974.

Thórdarsson, T., S. Self, G. Larsen, and S. Steinthórsson, Eruption sequence of the Skaftár Fires 1783–1785, Iceland, *Eos Trans. AGU, 68,* 1550, 1987.

Thoroddsen, T., Die Geschichte der islandischen Vulkane, *K. Dan. Vidensk. Selsk. Skr. Naturvidensk. Math. Afd. B., 9,* 14, 1925.

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Experimental Calibration of Hornblende as a Proposed Empirical Geobarometer

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The recent *Eos* report by *Anderson* [1987] reviewed prospects for using dated granitoid plutons as crustal nails in the reconstruction of descent or ascent of deformed crust during orogenic processes, if suitable geobarometers could be established. *Hammarstrom and Zen* [1986] and *Hollister et al.* [1987] have proposed an empirical geobarometer for calcalkaline plutonic rocks of tonalite and granodiorite composition based on the total Al content (Al_T) of calcic hornblendes. This proposition has generated considerable interest.

In a mineralogical study of five synmetamorphic calcalkaline plutonic complexes, *Hammarstrom and Zen* [1986] concluded that the linear relationship between Al_T of hornblende and pressure of crystallization, independently estimated from metamorphic assemblages in the country rock, could be used as an indicator of pressure of solidification. Their empirical curve, reproduced in Figure 1, was based on data from samples that crystallized at 1.5–3 kbar and 7–10 kbar. *Hollister et al.* [1987] tested and confirmed the proposed hornblende geobarometer with data for hornblendes from nine additional calcalkaline plutons that filled the gap from 4 to 6 kbar, and then added points at the low- and high-pressure ends. Their curve differs slightly from that of *Hammarstrom and Zen* [1986], with a smaller estimated error (Figure 1). Both groups emphasized that the geobarometer was restricted to calcalkaline rocks with specific mineral assemblages and to hornblende that crystallized near the solidus for the granitoids. The empirical geobarometer lacked reliable experimental confirmation when published, as discussed by Hammarstrom and Zen with particular reference to *Helz*'s [1982] review of the phase relations and compositions of amphiboles produced in experimental studies of natural rocks. We have new experimental data on hornblende compositions in a partly melted, vapor-absent tonalite that provides direct experimental calibration. This tonalite has been the subject of many previous experimental studies [see *Huang and Wyllie,* 1986].

Experiments were conducted in gold capsules in piston-cylinder apparatus at 10 kbar for durations of 1 day and 4–5 days, with negligible Fe loss to the capsule. Polished sections of experimental charges were examined with scanning electron microscopy, and mineral and glass compositions were analyzed by microprobe. The necessary long-run durations precluded use of an external oxygen fugacity buffer. We have evidence that the oxygen fugacity in the experiments is close to that of nickel-nickel oxide (NNO), and we believe that this is imposed by the iron-bearing components in the assemblage that is present

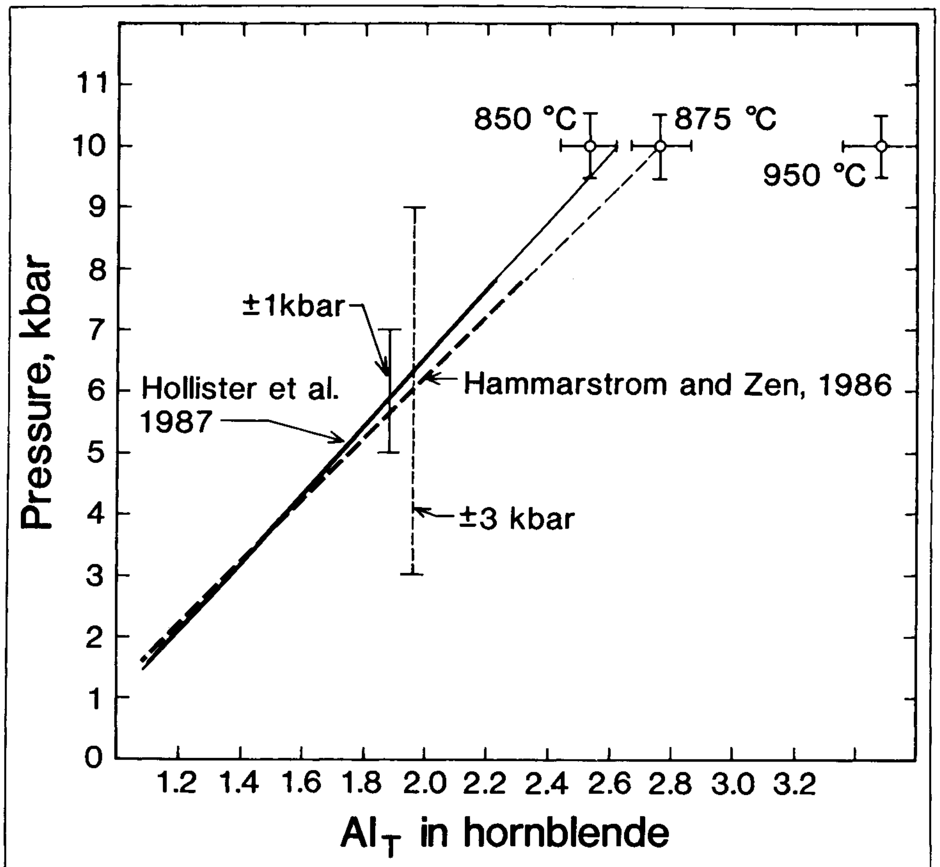

Fig. 1. The empirical curves of *Hammarstrom and Zen* [1986] (dashed line, estimated error ±3 kbar) and *Hollister et al.* [1987] (solid line, estimated error ±1 kbar), extrapolated to 10 kbar (lighter lines). The crosses represent Al_T in near-solidus experimental amphiboles in partly melted vapor-absent tonalite at 10 kbar and 850°–950°C, measured by electron microprobe.

in the capsule at the conditions of reaction. The oxygen fugacity is consistent with that deduced by *Hammarstrom and Zen* [1986] for the solidification of calcalkaline rocks in their study.

At 10 kbar the subsolidus assemblage is that of a garnet-tonalite. Amphibole compositions in near-solidus experiments are plotted in Figure 1. Error bars are based on a ±5% error in the pressure measurement and a standard deviation (2 σ) of 0.3% relative for Al_T calculated from replicate microprobe analyses of a compositionally homogeneous amphibole. The new calcic amphibole in the near-solidus 850°C experimental run plots very close to the empirical curve of *Hollister et al.* [1987]. Application of this geobarometer to the relict hornblende, with substantially lower Al_T contents, implies a pressure of solidification for the starting tonalite of between 2 and 3 kbar. Hornblende in an 875°C experimental run coincides with the empirical curve of *Hammarstrom and Zen* [1986], but this hornblende is subcalcic according to *Hawthorne*'s [1981] classification. While the phase assemblage at 850°C satisfies the mineral criteria for both empirical geobarometers, the other two fail because the 875°C run has no orthoclase, and the 950°C run contains no quartz, orthoclase, or biotite. The hornblende in the high-temperature run is significantly more aluminous than near-solidus hornblende and does not fall near the geobarometer curves. The results support the conclusion of *Hammarstrom and Zen* [1986] and Hollister et al. that the geobarometer is applicable only to rocks with the minerals specified above and at near-solidus conditions. Significant discrepancies are introduced if one of these minerals is absent. Additional experimental calibration is desirable for the empirical geobarometer and for other intensive parameters in addition to pressure, including temperature and a_{H_2O}, which affect the Al content of amphibole.

Our experimental results on hornblende provide the first direct calibration of the empirically defined geobarometer curve. Although many more experiments are required to establish the theory of the reactions that buffer amphibole compositions along various vectors [*Thompson et al.*, 1982], the fact that this calibration fits the extrapolated empirical curve supports the reliability of the indirect approach involving estimates of the pressure of country rocks to derive an empirical curve for the plutons. The agreement between the two approaches enhances the prospect that granitoid plutons will prove to be extremely useful in tracking the rise and fall of deforming crust.

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References

Anderson, J. L., Granite barometry and tectonics, *Eos Trans. AGU, 68,* 1143, 1987.
Hammarstrom, J. M., and E.-A. Zen, Aluminium in hornblende: An empirical igneous geobarometer, *Am. Mineral., 71,* 1297, 1986.
Hawthorne, F. C., The crystal chemistry of the amphiboles, in *Amphiboles and Other Hydrous Pyriboles — Minerology, Rev. Mineral. Ser.*, vol. 9A, edited by P. H. Ribbe, pp. 1–102, Mineralogical Society of America, Washington, D.C., 1981.
Helz, R. T., Phase relations and compositions of amphiboles produced in studies of the melting behaviour of rocks, in *Amphiboles: Petrology and Experimental Phase Relations, Rev. Mineral. Ser.*, vol. 9B, edited by D. R. Veblen and P. H. Ribbe, pp. 279–346, Mineralogical Society of America, Washington, D.C., 1982.
Hollister, L. S., G. C. Grissom, E. K. Peters, H. H. Stowell, and V. B. Gisson, Confirmation of the empirical correlation of Al in horneblende with pressure of solidification of calc-alkaline plutons, *Am. Mineral., 71,* 231, 1987.
Huang, W.-L., and P. J. Wyllie, Phase relationships of gabbro-tonalite-granite water at 15 kbar with applications to differentiation and anatexis, *Am. Mineral., 71,* 301, 1986.
Thompson, J. B., J. Laird, and A. B. Thompson, Reactions in amphibolite, greenschist and blueschist, *J. Petrol., 23,* 1, 1982.

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A Message From the VGP President

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This message is not of an inspirational nature. I hope that this is a relief to you; if you need inspiration I suggest that you follow the primaries closely in this election year. Instead, I've written a rather dreary piece about the nuts and bolts that keep the Volcanology, Geochemistry, and Petrology (VGP) Section going. These nuts and bolts are essential to the section, however. It may be useful to you, or you may be able to help.

You will be hearing more about the Geophysics Research Forum in the future in these pages. The AGU Council, with your help, will be trying to determine what important issues and priorities should dominate the science over the next few years. Similarly, the National Academy of Sciences–National Research Council's Board on Earth Sciences is planning to write a report on priorities and future opportunities in the Earth sciences. If you have ideas on where you feel the science should be heading, on priorities in the science, on which subfields should be emphasized and which deemphasized, please write me. It's important, as such exercises can profoundly affect the future and future funding of our science. VGP science is particularly exciting, and the best ideas must be included.

If you have ideas for a Chapman Conference, let me or AGU Headquarters know. As section secretary, Don DePaolo has the biggest job in VGP: looking after the scientific program for VGP for the AGU Fall and Spring meetings. I am most grateful to Don, as I am to Roz Helz who filled in for Don for this fall's meeting. If you have good ideas for symposia for the 1988 Spring Meeting, let Don know; you will enjoy the meeting more,